STORMWATER TREATMENT AREA NO. 3 & 4

PLAN FORMULATION

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12. FLEXIBILITY FOR PHASE 2

12.1 INTRODUCTION

The Everglades Forever Act (EFA) established an interim standard of 50 parts per billion (ppb) TP for surface waters entering the Everglades Protection Area. However, a lower final standard was anticipated at the time of Act passage, and (10 ppb) was defined in the EFA as a default value unless an alternative criterion is established through the state's rule-making process. The Florida Department of Environmental Protection (FDEP) is currently leading evaluations in support of determining the ultimate phosphorus standard.

Based on operational data from the Everglades Nutrient Removal (ENR) Project and Stormwater Treatment Area (STA) 6, waters exiting the STAs are expected to meet or exceed the interim goal of 50 ppb. However, in order to achieve long-term average concentrations as low as the anticipated final TP standard, actual treatment levels will likely need to achieve TP concentrations lower than 10 ppb. Macrophyte-based STAs cannot be reasonably projected to achieve TP levels that low. Therefore, it is reasonable to assume that under the currently anticipated phosphorus-related regulatory program, some form or combination of advanced treatment technologies will be needed to be able to comply with the final standard established through the state's rulemaking process, coupled with optimization of STA-3/4 performance. Efforts are currently underway to research candidate advanced treatment technologies that might support achieving long-term compliance with the lower final standard and to accelerate incorporation of those technologies into design and construction of STA-3/4 and the other STAs constructed to date.

Design of STA-3/4 must remain faithful to the general basis of design of all the other STAs completed to date, to the extent that the basis of design remains consistent with our current knowledge of treatment wetland design. Thus, no radical change from prior STA designs is anticipated. However, in light of the clear need for additional treatment beyond that achievable with macrophyte-based systems and considering the favorable treatment performance data generated through monitoring of the operation of the District's ENR Project over the past several years (average outflow concentrations in the 20-30 ppb range), the current design efforts should take advantage of new information that is available to help guide design of STA-3/4 in a manner that provides flexibility for integration of additional treatment technologies into the final design at some point in the future, and to permit optimization of the performance of STA-3/4.

During the course of preparing the Alternatives Analysis for STA-3/4 design, the research results available during the summer of 1999 were reviewed, and recommendations were generated regarding possible design features that might promote design flexibility. This chapter provides an update on the information currently available for the candidate advanced treatment technologies (ATT). Each technology is briefly described, and published results from applicable research efforts are summarized. Considerations for completion of research and formulation of design criteria are described. Opportunities for incorporation of ATT in the design of STA-3/4 are discussed and design features that offer flexibility for both the final design of the treatment system and optimization of the performance of the initially constructed system are highlighted.

12.2 ADVANCED TREATMENT TECHNOLOGIES

Over two dozen water quality treatment technologies were originally screened in the Desktop Evaluation conducted for the District by PEER Consultants/Brown and Caldwell (reference 1). Five of those were originally proposed for additional investigation, and research programs focused on four other treatment technologies were required by the U.S. Army Corps of Engineers as conditions of the Section 404 permit for construction of the STAs. At various times referred to as “superior” or “supplemental”, these technologies are currently referred to as “advanced” and will be assigned that description within this report. Five advanced technologies remain under research by the District, the FDEP, and/or the U.S. Army Corps of Engineers as potential treatment technologies that could be linked to macrophyte-based STAs:

- Chemical Treatment/Solids Separation
- Low-Intensity Chemical Dosing in Wetlands
- Managed Wetland Treatment Systems

- Submerged Aquatic Vegetation/Limerock
- Periphyton-Based Stormwater Treatment Areas

The general performance goal for each of these ATT is to remove total phosphorus (TP) from surface waters released from Lake Okeechobee or runoff originating from the Everglades Agricultural Area (EAA) to TP averages of 10 ppb or less.

For planning purposes, the TP concentration in water entering STA-3/4 is expected to average about 120 ppb following implementation of best management practices (BMPs) on the farms in the EAA. Also, for planning purposes, the ATT must be able to either:

- Treat this EAA runoff water ("post-BMP") with about 120 ppb to the final goal, which for this discussion can be assumed to be 10 ppb, or
- Treat waters leaving the STAs ("post-STA") water from about 50 ppb to the final goal

The EFA set a date of December 31, 2001, for completion of research on these candidate advanced technologies and development of an appropriate strategy by 2003 for achieving compliance with the anticipated TP standard by 2006. Current efforts are focused on accelerating this process of research and decision-making. Specifically, incorporation of ATT into the footprint of STA-3/4, with particular focus on a potential post-STA application of an advanced technology, is being considered to increase the performance of that system. Preliminary discussions to date have focused on the candidate treatment approaches considered most likely to generate a final, "ionically balanced" product water, namely Submerged Aquatic Vegetation (SAV) and Periphyton Based Stormwater Treatment Areas (PSTAs). However, all of the candidate ATT remain under investigation and consideration. In the final analysis, some combination of these various technologies may be required to consistently achieve the ultimate TP standard set through the rulemaking process.

This report section highlights the promising information that is currently available to advance this planning, as well as the existing information gaps that could impede successful implementation. As discussed later in this section, planning-level evaluations can at this time only proceed based on information available to date and best professional judgement. Concurrently, research efforts to fill the referenced information gaps are continuing with the goal of ultimately increasing future planning and design reliance on data acquisition and analysis. In this manner, decision-making risk will decrease over time as more and more data become available upon which design decisions may be formulated. This approach generally is consistent with that followed in the design of the ENR Project, which clearly has been instrumental in demonstrating the range of capabilities of macrophyte STAs at this scale of application.

12.2.1 Chemical Treatment and Solids Separation

On behalf of the District, HAS Engineers & Scientists/Conestoga Rovers (HAS) is completing evaluation of several chemical treatment/solids separation (CTSS) approaches. These strategies are similar in that they use chemicals for TP precipitation (i.e., iron or aluminum salts, with or without polymers as coagulant aids). Several different methods for removing the precipitated TP were considered. These included:

- Direct filtration using conventional filtration technologies such as sand, coarse activated carbon, or other granular material
- High-rate balasted sedimentation using special clarifiers and microfine sand to promote settling
- Dissolved air flotation where flocculated particles are attached to fine bubbles and removed by skimming
- Microfiltration using high pressures and membranes with ultra-fine pore sizes

Phases 1 and 2 of the CTSS project were completed by a team led by Metcalf & Eddy. Phase 1 tests included bench-scale evaluations of the comparative TP removal capabilities of aluminum and iron salts for EAA water. Chemicals that showed the most promise in Phase 1 were further evaluated during Phase 2 by testing a range of influent TP levels, chemical dosage, use of polymers, use of adsorbents, and pH conditions. The principal findings of the CTSS Phase 1 and 2 research were summarized in the Everglades Interim Report (reference 2) and include:

- TP levels of 10 ppb can be achieved from a range of influent TP levels from 12 to 430 ppb.
- Removal of TP was most efficient for high TP inflow waters.
- At high metal doses (>20 milligrams per liter [mg/L] aluminum or >40 mg/L iron), filtration and settling resulted in similar TP outlet concentrations.
- Orthophosphate was easier to remove than polyphosphate and organic phosphorus components of the influent water. High dosages of metal salts are necessary to remove organic phosphorus and polyphosphate.
- pH adjustment above 9 standard units significantly increased TP removal – significant lime addition was necessary to achieve this target pH, and acid was then required to reduce the pH of treated waters to near neutral marsh-ready pH..

Fieldwork for microfiltration was conducted on post-BMP and post-ENR waters. A final report was submitted in May 1998 (reference 3). Principal results from the one-year demonstration project were:

- Chemical treatment followed by microfiltration is capable of achieving <10 ppb TP.
- Ferric salts are preferred due to their ability to extend filter run times and due to environmental perceptions.
- Post-BMP utilization of this technology would require a very large equalization basin, which negatively impacts cost-effectiveness of the technology.
- Bioassay and algal growth potential tests demonstrated no sustained adverse impact on receiving water biota.
- Membrane technology has the potential to be used for TP reduction at higher target outflow concentrations (i.e. 20 – 30 ppb).

Operation of the CTSS pilot facilities comprised Phase 3 research. The operational testing was started in May 1999 and completed in December 1999. HAS has completed a preliminary draft of their test findings, and this work is currently undergoing SFWMD and peer review. The Phase 3 work focused on a comparison of the various solid separation techniques as a pilot scale demonstration project with the following objectives:

- Identify and demonstrate an optimized CTSS process for which operating conditions can be described and full-scale costs projected;
- Conduct sampling adequate to complete a Supplemental Technology Standard of Comparison (STSOC) evaluation as described by PEER Consultants/Brown and Caldwell Joint Venture; and,
- Develop process criteria and experience needed to design a full-scale CTSS system.

The basic test facilities consisted of two parallel rapid mix/flocculation/parallel plate sedimentation pilot trains, followed by a total of nine 8-inch diameter columns that were used to test various adsorption and filtration media after gravity separation.

Summary of Observations/Conclusions

- Key findings of Phase 3 of the CTSS studies are as follows:
- The CTSS treatment produced a settled, gravity clarified effluent of less than 10 ppb of TP on either Post-STA or Post-BMP EAA surface waters using either ferric chloride or alum as coagulants. The principal unit processes used in achieving these results were chemical coagulation, flocculation and inclined plate enhanced clarification.
- Several other vendor technologies produced treated effluent of less than 10 ppb of TP. These technologies should be further evaluated if the conventional CTSS system is determined not to be the most practicable scenario at some point in the future.
- Technologies and treatment processes, including dissolved air flotation, direct in-line filtration, direct filtration and activated alumina treatment proved ineffective at reducing the TP content of the stormwaters and no further testing of these technologies is recommended.
- Bioassay and AGP studies conducted on representative CTSS feed and effluent samples demonstrated no significant adverse impact on receiving waters. The CTSS

process reduces the alkalinity, color and pH of treated waters and use of a treated effluent buffer cell has been suggested for incorporation in to the full-scale design for effluent conditioning.

- Residual solids produced by the CTSS process contain no hazardous constituents as defined by the toxicity characteristic leachate (TCLP) procedure. Full-scale conceptual designs have included recommendations for direct application of residual solids on land adjacent to the treatment facilities.
- Additional long-term residual solids investigations should also be completed to assess the efficacy of direct land application alternatives, including better estimating impact on crops, and perception of local farmers as to the beneficial use of these solids on their lands ……

Prior to full-scale implementation, construction and operation of a prototype CTSS facility ranging from 100,000 to 1 million gallons per day was recommended by HSA. The technology has not been tested on a true demonstration scale, and thermal, wind loading, and other environmental and scale-up effects have not been evaluated.

A key issue associated with any of the chemically-based ATT is the concern with whether the produced water will be ionically similar to downstream water quality in the Everglades. If not, it would not be considered "marsh ready" since unacceptable impacts to downstream aquatic systems could occur. It was beyond the scope of the CTSS project to assess the impact of the chemically treated water on downstream receiving wetlands. However, work being conducted for the MWTS project (see below) should shed light on the impact of chemically treated water on the immediate receiving wetland, and on the amount of wetland needed to ionically condition chemically treated water to restore it to a "marsh ready" condition.

12.2.2 Low Intensity Chemical Dosing in Wetlands

Low Intensity Chemical Dosing (LICD) refers to the use of chemical coagulants such as ferric iron and aluminum to precipitate phosphorus, and subsequent use of the wetland environment for filtration and sedimentation of these particulates to reduce concentration of TP in surface outflows. The original LICD concept differed from CTSS and Managed

Wetland Treatment Systems in that the chemical addition and sedimentation occur exclusively within the macrophyte-dominated STA environment. This proposed advanced technology is only being considered for TP removal in post-STA surface waters.

Phase 1 and Phase 2 of the LICD research were conducted on behalf of the Everglades Agricultural Area Environmental Protection District, the FDEP, and the District by the Duke University Wetland Center (reference 4-5). Phase 1 was intended to determine the feasibility of LICD to meet the proposed final TP standard of 10 ppb. Phase 2 was a demonstration project intended to develop management practices for enhancing performance of LICD. Phase 1 LICD research began in May 1998. Phase 2 research began in February 1999. Phase 2 field testing was completed in March 2000. A preliminary draft report is being prepared at this time.

Key research findings from Phases 1 and 2 are summarized as follows:

- Chemical treatments with coagulant alone affect TP speciation, typically changing dissolved phosphorus to particulate phosphorus. Initial chemical doses which ranged from 1.4 to 2.7 mg/L as Al, and 2.8 to 5.6 mg/L as Fe (50 to 100 mM dose as the metal) were ineffective in reliably reducing TDP below 10 ppb.

- The concentrations of metals needed to reduce TDP to below TP target levels are higher than originally conceived in the concept of “low intensity” chemical dosing. In situ dosing of 200 to 600 mM for both ferric iron (11 to 33 mg/L) and aluminum (5 to 16 mg/L) appeared to reliably reduce TDP concentrations to the 5 to 10 ppb level in later mesocosm tests (starting from a post-STA TP concentration of about 40 to 50 ppb).

- Use of coagulant alone was not effective in removing particulate P. The use of organic polymers in the form of PAMs and cationic coagulant aids was demonstrated to be required to flocculate colloidal particulate phosphorus into a settleable particle.

- Based on batch flow mesocosm studies, at least 3 to 4 days are required to achieve adequate flocculation and settling for TP removal.

- Additional mechanical processes appeared necessary to allow LICD to achieve project goals. These processes included rapid mixing and flocculation with the use of polymers to promote chemical coagulation and solids sedimentation.
- The mesocosms appeared to function as continuous flow stirred tank reactors (CSTRs), and thus were not capable of showing the sedimentation / filtration gradient that would be expected in TP as flow moves longitudinally from the chemical addition point to the outlet.
- The mesocosms contained few macrophytes or SAV and probably are thus not representative of the additional phosphorus sorption / filtration and then decay / feedback that would be expected.
- There was some evidence that the accreted soils have excess phosphorus storage capacity, and do not feed back phosphorus under anaerobic conditions.

Some of the key information that remains needed prior to consideration of incorporating LICD into the STAs includes the following:

- Accretion rate of solids within a flow-through LICD system and effects on system life, height of enclosing levees to ensure a given system life, and the possible need for cell rotation and solids harvesting and disposal
- Methods available for chemical additions over a large enough wetland footprint to minimize excessive local accumulations of residuals
- Effects of flow-through operation at sustained high flow velocities on sediment accretion and resuspension
- Environmental effects of accreted metal-bearing residuals in the wetland environment
- Preferred physical conditions for chemical dosing and mixing in terms of water depth, plant community characteristics, and area requirements

On the basis of the currently available information, LICD is not a candidate for integration with the existing STAs. The District is implementing supplemental studies of

LICD using the ENR test cells; additional clarification on the utility of this AT should be available within the year.

12.2.3 Managed Wetland Treatment Systems

Managed wetland treatment systems (MWTS) are a combination of chemical dosing and solids separation with a constructed wetland for final polishing and ionic conditioning. Unlike CTSS described above, the MWTS alternative advanced technology is viewed as a more passive system using a pond for chemical addition, mixing and gross solids collection and harvesting. With the ability to apply chemical doses within a pond environment, the MWTS option potentially allows treatment of either post-BMP or post-STA waters without mechanically based tanks or other similar infrastructure considered incompatible with the Everglades landscape.

The MWTS research and demonstration project began in November 1998; the District retained CH2M HILL to conduct this work. A research and demonstration plan was prepared in January 1999 (reference 6), and District and FDEP approval has been received. Fieldwork in the ENR test cells began in July 1999. Bench-scale testing of alternative chemical coagulants and dosages was completed during the first quarter of 1999; experimentation is ongoing regarding residuals stability and potential sludge management issues. The first six months of testing at the ENR test cells provided a baseline calibration period for the chosen experimental design, the paired watershed design. The calibration period is a critical part of this experimental design. The key elements of the paired watershed design includes the study of two to several watersheds, usually sub-watersheds that have similar geology, hydrology, climate and weather effects. One watershed is used as a control unit, where no treatment is applied to study the effects on water quality, and the second where the treatment is applied.

A pretreatment period is incorporated during which no treatment is applied to any of the experimental units, but monitoring data are collected on the parameters that will be studied for treatment effect. The data collected during the pretreatment period, known as the calibration period, are used to establish the relationship between the experimental units in terms of the water quality parameters of interest. Data collected during this period are used to produce a regression equation known as the calibration equation.

The control unit is monitored throughout the calibration and treatment periods, to control for effects of weather, climate and other seasonal effects. This allows the determination of the magnitude and significance of the treatment effect separate from stochastic effects, and without the need for experimental replication. The design of the chemical treatment units for the Phase 1 testing at the ENR was completed in the fourth quarter of 1999. Final modifications to the design were completed after a vendor was selected. Pilot plants were ordered in late October for delivery in late January. Installation and initial system start up and testing occurred during the first quarter of 2000.

Calibration Period

There are three pilot plants – 2 at the north ENR test cell site and 1 at the south ENR test cell site. At the north ENR site, one plant is designed to test the effects of iron as the coagulant; it pretreats water directed to North Test Cell (NTC) 2. The other plant is designed to test the effects of aluminum as the coagulant; it pretreats water directed to NTC 4. NTC 3 is the control cell and receives water (from the pilot plant splitter box) that has not been chemically treated. The single plant at the south ENR test cell site can be directed to flow to either south test cell (STC) 5 or STC 7. STC 6 at the south ENR study site is the control cell.

For the six-month calibration period at the NTCs, the inflow TP concentration was greater than the outflow concentration. However, this was generally reversed for the STCs. For both locations, most phosphorus is in the particulate form. Time series plots of the data show remarkable similarity in patterns of inflow and outflow TP concentration within each group of the two groups of test cells.

Mass balances for the phosphorus series series were prepared. For the calibration period of MWTS testing at the NTCs, there is a net removal of TP on a mass basis. This is not the case, however, for the STCs where there is evidence of net export of phosphorus. For the NTCs, the monthly average TP removal is in the range of 1 to 2 mg/m^2; the cumulative TP removal for six-months ranged from 6 to 8 mg/m^2. The STCs by contrast do not show a clear pattern of net TP removal on either a monthly or cumulative basis.

The summary of key findings during the calibration period is as follows:

- Nutrient Mass Balance—net removal of phosphorus and nitrogen is occurring at the NTCs. By contrast, removal rates at the STCs range from negative to only slightly positive.

- Outcome of the Paired Watershed Calibration—statistical analysis of the TP data yielded good calibration equations for the north and south test cells. Thus, the calibration period is considered complete.

- Chemical Treatment at ENR—with the completion of the calibration period and the treatment unit design, the chemical treatment phase of testing at the ENR began.

- PACL Testing—laboratory evaluations verified that PACL is as effective as alum for phosphorus removal from ENR waters. Testing also established PACL formulation and dose, and polymer and dose. Use of PACL rather than alum may be favorable in that it reduces the risk of mercury methylation.

Results of Chemical Treatment Testing at ENR Test Cells

Two chemical treatments pilot units began operating at the NTCs in the third week of February. The single pilot unit at the STCs began operating in the third week of March. Initial results are available for the startup period. Early results from the NTCs are as follows:

- Fe and Al treatments are reducing TDP, SRP, DOP, TN, TKN, org-N, TOC, and color concentrations in pilot unit effluent relative to the control for inflow to the receiving wetland

- With some operational adjustments TDP concentrations for both treatments have ranged from 12 to 18 ppb; however excursions have been higher

- It appears that the wetland is contributing TDP, as concentrations in wetland outflows have been higher than the pilot plant influent for both treatments

- Due to episodic floc overflow TP and TPP concentrations in pilot plant effluent (inflow to wetland) is not consistently lower than the control; however, TP and TPP concentrations in wetland outflow is lower for the treatments compared to the control
- TPP in pilot unit effluent is quickly removed at the head of the wetland

Treatment units are performing better after operational adjustments in May. Some adjustments to dosing have been required, due to higher TP concentration during startup as compared to waters used in jar tests used for setting dosages. Polymer has been switched to the A130 anionic polymer utilized in CTSS and LICD. Coagulant dosages have been increased to 20 mg/L as Al and 40 mg/L as Fe, from 14 mg/L and 27 mg/L respectively. Adjustments to the mixing regime have been implemented. Ongoing performance optimization of the pilot units is expected to yield an effluent with TDP concentrations of less than 10 ppb, and improved floc removal.

Design and Testing of a Chemical Treatment Pond

Design of the chemical treatment pond to be applied for this research study has been completed, and construction of the pilot pond will begin in June 2000. However, insufficient design information is currently available to apply this proposed technology to STA design or retrofitting. Chemical treatment is intended as the primary method of phosphorus removal. The primary chemical to be used for phosphorus removal will be poly-aluminum chloride (PACL). An anionic polymer will also be added to increase particulate removal efficiency in the pond.

The treatment pond will be used for solids contact, solids separation, and residual solids storage. The pond will be lined with 40-mil high density polyethylene (HDPE) geomembrane and has enough solids storage volume for approximately 3 months of operation at which point solids will be removed and trucked for disposal. Chemically treated water will flow through 2 distribution pipes running along the base of the pond. Each distribution pipe is located in a two-foot deep trench sized to hold about 3 days of precipitated solids. The distribution pipes are equally spaced and have hole patterns to provide uniform water distribution.

Once the pipe trenches fill with solids, solids contact will occur with the inlet water. Phosphorus removal occurs as water flows upward through the solids layer. A weir box at the far end of the pond will be used to set the water level in the pond and to collect treated water. Treated water will flow over the weirs and out through the discharge pipe at the base of the weir box.

In short, considerable progress has been made since the summer of 1999 toward evaluation of MWTS as a candidate ATT in support of Everglades restoration. However, all results remain very preliminary and conclusions regarding the following types of information are still needed prior to any potential consideration of MWTS concept incorporation into design efforts for STA-3/4:

- Preferred chemical(s) and dosing requirements
- Physical design parameters to allow effective dosing, mixing, flocculation, and sedimentation within a mechanically simple pond system
- Effective methods for residual collection and management in a pond environment
- Techniques and costs for residuals management or disposal
- Target post-pond TP concentration prior to discharge to downstream wetland cell (design goal for the first stage process)
- Effectiveness of wetland environment for final polishing, rates of solids accretion, and environmental effects of metal-bearing residuals on wetland biota

Information relevant to these questions will be generated by the ongoing research program, which is expected to be completed by May 2001.

12.2.4 Submerged Aquatic Vegetation/Limerock

The proposed Submerged Aquatic Vegetation/Limerock (SAV/LR) ATT includes the use of SAV-dominated wetlands for pH elevation (CO_2 stripping) combined with exposed limerock for chemical precipitation. This proposed technology is being considered at both the post-BMP and post-STA locations. Phase 1 SAV/LR research was conducted from May 1998 through February 1999 by DB Environmental Laboratories (DBEL). A draft final report on Phase 1 has been issued (reference 7). An interim project was funded by the Everglades Agricultural Area Environmental Protection District from March 15 through August 15, 1999 (reference 8). This project allowed continued collection of operational monitoring data until the District could resume funding for this technology evaluation. Phase 2 research and demonstration efforts funded by the District were resumed on August 30, 1999. This effort was funded for a contract period of 100 weeks (reference 9). .

Principal findings of the Phase 1 SAV/LR research include:

- SAV mesocosms operated at hydraulic residence times between 1.5 to 7 days removed TP at 3.3 to 11.8 $gP/m^2/yr$ at an influent TP concentration of about 99 ppb.
- Post-BMP SAV mesocosms were able to attain average outlet TP concentrations as low as 18 ppb at a residence time of 7 days during this 9-month study period. Post-STA SAV mesocosms were able to attain an average outlet TP concentration of 14 ppb during the 9 month Phase 1 period. TP settling rate in post-BMP SAV mesocosms during this same period was a function of loading rate and ranged from 69 to 182 m/yr. The apparent TP settling rate in the post-STA SAV mesocosms was 10 m/yr, conforming to the apparent relationship between TP mass loading and settling rate.
- The removed TP could not be completely accounted for in the vegetation or the sediments, resulting in uncertainty concerning the sustainability and accuracy of the estimated removal rates.
- At a fixed water depth, performance was a function of hydraulic residence time. However, TP removal was highest in the shallowest tested water depth in the post-BMP mesocosms (i.e., 40 cm). These data indicated that increasing hydraulic residence time (HRT) by increasing water depth does not enhance SAV performance.

- SAV mesocosms were effective at removing soluble reactive phosphorus (SRP), with nearly 100% removal at 7 day hydraulic residence time, but were ineffective for removing particulate phosphorus at low influent concentrations
- TP removal performance in SAV mesocosms is consistent over a diel period.
- Limerock unit processes at the mesocosm scale had very little effect on the precipitation of calcium-bound phosphorus but did have a measurable effect on filtration and sedimentation of particulate P.

SAV/LR decreased the total and methyl mercury levels in post BMP waters and increased the concentration of methyl mercury in post-STA waters. Data presented in the report indicated that post-BMP SAV/LR waters had some acute toxicity to fish and water fleas. Kadlec provided a critique of the interpretations of the DBEL SAV/LR work (reference 10). Key conclusions based on Dr. Kadlec's memorandum include the following:

- The central premise of SAV/LR (pH elevation through SAV productivity followed by TP co-precipitation with calcium (Ca) on limerock surfaces) should be rejected based on this research. While not yet confirmed, the phosphorus removal demonstrated appeared related to incorporation in SAV and periphyton biomass.
- The inability to close the TP mass balance at the mesocosm scale leads to uncertainty concerning the accuracy, interpretation, and use of the research results.
- The research was conducted during a grow-in period and results may not be indicative of sustainable levels of phosphorus uptake or accretion.
- The research spanned less than one year; therefore, the seasonality of the measured processes is not fully known.
- The lowest possible outlet average TP concentration using SAV alone is extrapolated to be 12 ppb.
- Use of limerock for the sole benefit of particulate TP removal is unlikely to be a cost-effective treatment approach.

- If only the measured accretion of TP is included, the demonstrated sustainable TP removal rate constants ranged from 5 to 26 meters per year (m / yr), with an average of 13.3 m / yr.
- The mesocosm research performed to date does not allow assessment of the possible effects of full-scale linear water velocities on treatment performance.
- SAV biomass decreased markedly in the post-STA mesocosms indicating a non-sustainable ecological condition at low TP concentrations.
- Results from the SAV mesocosm studies are at variance with the results from ENR Cell 4, with a reported minimum mean TP settling rate twice the value observed at the larger scale over an apparent sustainable period.
- Engineering scale-up and economic analysis by DBEL ignore the effects of residuals management, water level control, and site preparation and therefore are not yet defensible as the basis for SAV / LR incorporation into STA designs.

The SAV/LR Phase 1 research was augmented by limited studies in the ENR Project Cell 4, which is SAV dominated. Dr. Walker's analysis of the District's monitoring records for Cell 4 documented an average TP settling rate of approximately 36 m/yr over 4 years of full-scale research operations (reference 11). The performance of the SAV dominated Cell 4 is considerably greater than the average of the *Typha* (cattail) dominated ENR cells (11 m/yr) during this same period. About 4 cm of accreted sediments were observed in this portion of the ENR, indicating the likely fate of the removed phosphorus in a post-STA environment.

Interim research conducted by DBEL between March and August 1999 (reference 8) provided additional insight into the performance of SAV/LR mesocosms over a longer operational period. Final TP effluent concentrations generally increased at the post-BMP research site during this period, from a typical range of 10 to 15 ppb in Phase 1, to 15 to 25 ppb. This declining performance was attributed to multiple factors including higher TP inflow spikes, lower inflow calcium concentrations, and senescence of one of the dominant SAV species, *Chara*, a macroalga that appeared to be a "pioneer" that does not dominate the SAV in the large-scale system in Cell 4 of the STA-1W.

There continued to be little effect of depth on TP effluent quality, adding to the observation that increased depth as a method of increasing hydraulic residence time does not result in a proportional increase in TP removal performance. Other new findings from this interim research period included:

- In side-by-side comparisons at the post-BMP mesocosm scale, SAV out-performed cattails, and cattails with SAV outperformed cattails with duckweed (*Lemna*).
- SAV drydown in post-STA waters was detrimental to performance, resulting in outflow TP concentrations above inflows for a period of one week. Outflow concentrations from these mesocosms remained high throughout the remainder of the study period compared to pre-drydown conditions due to poor regrowth of the SAV species, *Chara.*
- Initial results from a side-by-side comparison of post-STA SAV performance on three different soils (peat, limerock, and sand) indicated little difference in TP removal performance (none of the outflows were consistently lower than the inflows) but slightly better growth of the SAV species on the peat soils.
- A high loading rate post-BMP SAV mesocosm was dismantled in March 1999 after 302 days of operation, and evaluated for plant biomass production and accreted sediments. There were no initial sediments in the tank, so all new material could be easily sampled. With an average HLR of 140 cm/d, approximately 13.9 g P/m^2/yr was lost from the water column. Sampling of vegetation and sediments accounted for about 67 percent of this TP with 1.48 g P/m^2/yr in the SAV and 7.9 g P/m^2/yr in the newly accreted sediments. The accreted sediment depth was about 2.8 cm.

Phase 2 research of the SAV/LR technology has been underway for about 9 months and has further addressed many of the issues described above. Key findings are reported in DBEL 2000a (reference 9) and in DBEL 2000b (reference 12), DBEL 2000c (reference 13), and DBEL 2000d (reference 14). Key new findings at the SAV/LR mesocosm scale were reported through January 2000 and include:

- The post-BMP water depth mesocosm experiment was ended in November 1999 after about 15.5 months of operation. Approximately 58 to 86 percent of the removed TP was accounted for in the plants and newly accreted sediments (about 2 cm). The sediment TP storage rate in these 10 cm/d hydraulic loading rate (HLR) mesocosms varied from 0.84 to 2.02 g P/m^2/yr. SRP removal was correlated with high daytime pH and calcium loss in the water column of these tanks, indicating that co-precipitation of phosphorus and Ca is an important removal mechanism for the SAV technology.

- Variable HLR at a constant water depth (80 cm) has a strong influence on effluent TP in the post-BMP SAV/LR mesocosms, in contrast to the lack of a marked effect of water depth. Long-term average TP outflow concentrations ranged from 32 to 63 ppb for HLRs between 11 and 53 cm/d (with an average inflow TP of about 100 ppb). Outflow concentrations after the LR tanks were lower, ranging from 18 to 45 ppb.

- A spatial/temporal study conducted in the post-BMP static water level tanks (0.4, 0.8, and 1.2 m deep) found no consistent diel pattern for TP or SRP in the tank outflows. However, there was clear vertical stratification of dissolved oxygen, Eh, calcium, pH, and alkalinity in afternoon samples.

- Harvesting of SAV (about 50 percent removed) reduced treatment performance for about 7 weeks before eventual recovery to pre-harvested effluent TP concentrations.

- Post-STA SAV mesocosm performance on three different soils was reported for the 7 month period from July 1999 to February 2000. The average inflow TP during this period was 17 ppb and the HLR was 30 cm/d. Mean outflow TP concentrations were 14, 13, and 15 ppb for limerock, peat, and sand soils, respectively. SAV biomass on the peat soils continues to be higher than on the other types of soils.

The SAV north (NTC-1 and NTC-15) and south test cells (STC-4 and STC-9) have been modified by DBEL from their original configurations. Water levels were raised, inflow distribution manifolds were installed, and herbicide was sprayed in the cells to reduce dominance by cattails. *Chara* and *Hydrilla* were the dominant SAV species in these cells. Monitoring of the two north test cells was conducted for a period of four months at an HLR of about 10 to 13 cm/d and continued for about 3 months at about 40 cm/d. Tracer tests indicated that the volume of these cells was likely higher than planned and that the cells' hydraulic performance can be modeled as about 1.7 to 3.3 tanks-in-series (TIS), with higher values at deeper depths. Short-circuiting of flows was observed over the top of the SAV community following an increase in water levels.

At the north SAV test cells, an average influent TP of about 73 ppb was reduced to an average effluent TP of about 23 ppb during this period. TP performance at the south test cells was poor with no net reduction between an average inflow TP of 18.5 ppb and an average outflow of 18.5 ppb. This poor performance was attributed to the presence of *Hydrilla* in these test cells and the recalcitrant nature of the TP at this site. Evidence from other work in these test cells by the District and CH2M HILL indicates that these outflow TP concentrations are observed regardless of plant community type and may reflect an effective lower limit for performance in these peat-soil mesocosms.

Operational monitoring results from Cell 4 in STA-1W have been intensively analyzed as part of the SAV/LR Phase 2 research (references 9, 12, 13, and 14). The long-term average HLR to this cell has been about 13 cm/d. There was a 3-year period of relatively poor performance in this cell after startup and during grow in of SAV. TP removal has been consistent since mid 1997 with an average outflow concentration of about 15 ppb. In 1999, about 75 percent of the weekly outflow TP concentrations were less than 15 ppb. The annual average TP removals in this cell have varied from about 0.66 to 1.73 g $P/m^2/yr$ since 1995. The average TP settling rate was 26.1 m/yr for the period from 1995 through mid-1999. There is essentially no reduction in TP concentration in the last 2/3 of this cell, indicating an apparent achievable background TP concentration of about 10 to15 ppb on these peat-based soils. A tracer test conducted in December 1999 and January 2000 indicated that this cell has significant short-circuiting along lateral borrow canals. The measured HRT was actually higher than the nominal value, possibly indicating that this cell is deeper than suspected. The hydraulic model that best fit the tracer data was 1.3 tanks-in-series.

The SAV/LR technology development team has also been involved in various activities related to SAV colonization of STA-1W Cell 5. This cell was initially flooded in the spring of 1999 and has had very high water column TP concentrations since that time. Small-scale lime addition studies indicated that water column TP, SRP, and color could be reduced for about 2 to 3 weeks at Ca concentrations of 66 and 198 mg/L. Macrophyte colonization in Cell 5 has been very slow, apparently due to high water depths and color (low light transmission). Recent work indicates that the SAV species are widely distributed in Cell 5 but at low densities (reference 14).

The SAV/LR project has made significant progress on development and calibration of a performance forecast model. A dynamic simulation model has been designed to track TP concentrations in the water column, in active storages (plants and soils), and inactive (removed) storages. This model has been calibrated with Cell 4 operational data and provides reasonable estimates of system performance. This model was used to provide estimated performance improvements associated with various alternatives being considered for enhancing Cell 4 hydraulics. The model indicated that changing the TIS from 1 to 4 would result in a 10 to 13 percent increase in the net TP settling rate and would lower the long-term average outlet concentration by 14 to 29 percent. The model also was used to predict that TP outflow concentrations are likely to be much higher under conditions of higher HLRs.

Critically important information still needed to support defensible SAV design criteria includes the following:

- Stability of TP storage in accreted sediments under full-scale linear velocity ranges
- Results from mature SAV-dominated lakes for sustainable sediment TP accretion rates
- Ecological requirements and TP removal performance of SAV species and management practices needed to sustain dominance by desired species. Of special

importance are water level management guidelines and control techniques to reduce competition by emergent macrophyte and phytoplantonic algae populations

The best source of guidance for developing full-scale SAV/LR design criteria for incorporation of this ATT in the STA-3/4 footprint continues to be ENR Cell 4. This design guidance consists of replicating the environmental conditions of water depth and plant community composition known to be present in Cell 4. ENR Cell 4 only includes SAV and the LR portion of this proposed technology has not been demonstrated to be an effective treatment "unit".

It is the District’s intent to continue to monitor and evaluate the performance of large-scale SAV communities in Cell 5 of STA-1W, Cell 3 of STA-2 and Cell 1B of STA-5. That monitoring and evaluation will include assessment of operational needs and startup requirements, and is intended to supplement the results of the continuing research effort. Reproduction of the current operations of Cell 4 would require little or no modification to the design of the physical works necessary for completion of STA-3/4, although the inclusion of cells in series would facilitate that incorporation.

12.2.5 Periphyton-Based Stormwater Treatment Areas

PSTAs have been proposed for consideration as an ATT for post-STA TP removal (reference 15-16). This option consists of creation and maintenance of periphyton-dominated wetland ecosystems which in the natural Everglades system have been shown to be capable of achieving very low (< 10 ppb) TP levels. Accreted sediments with sequestered TP would either be stored within the confines of the system or be regularly exported and disposed.

Kadlec (reference 17-18) and Kadlec and Walker (reference 19) provided preliminary evaluations of the feasibility of the PSTA concept. Those initial evaluations identified a number of possible constraints for this proposed treatment option, including a general lack of any quantitative performance or design information. The District's PSTA Research and Demonstration Project, conducted by CH2M HILL, was initiated in July 1998 to conduct basic research needed to address technical, environmental, and economic feasibility. On a parallel track, Dr. Ron Jones/FIU is scheduled to conduct

PSTA research for the U.S. Army Corps of Engineers within the footprint of STA-1E. Most of the proposed STA-1E experimental system was constructed during the spring of 2000 and operation is expected to commence during the summer of 2000.

Development of the CH2M HILL PSTA research plan, construction of portable PSTA mesocosms (Porta-PSTAs) and modifications to the 3 south ENR PSTA Test Cells were completed during the first quarter of 1999 and operational monitoring began at that time. The first year of operation and Phase 1 of the PSTA research and demonstration project was completed in March 2000. Phase 2 operations began in April 2000 with continuing data collection from the PSTA test cells and the Porta-PSTA mesocosms. A field-scale PSTA test system is currently under construction immediately west of STA-2 and is scheduled to be operational during the summer of 2000. Monitoring through the second quarter of 2001 is planned.

Preliminary findings from the CH2M HILL PSTA project are reported in a number of quarterly reports (references 20-22) and may be summarized as follows:

- Following an initial grow-in period of about 2 to 3 months, the PSTA mesocosms provided consistent TP removal at a variety of loadings, soil types, and water depths. At the south test cells, average inflow TP concentrations in cells with constant water flows and depths have been lowered from about 25 ppb to 14 ppb on shellrock soils and to about 18 ppb on peat soils. Variable water depths and flows resulted in higher average TP outflow concentrations on shellrock soils (average about 18 ppb). Lowest quarterly average TP concentrations have been about 11 ppb.

- Average TP outflow concentrations from the Porta-PSTAs since the end of startup have been similar to the Test Cells with averages between 14 and 18 ppb at similar average inflow TP concentrations and loads. Lowest quarterly average TP outflow concentrations were observed to be 12 to 13 ppb on shellrock and peat soils.

- A batch study conducted from January to March 2000 found that water column TP concentrations increased slightly after the cessation of water inflows and with internal water re-circulation. These results indicate that the achievable background TP concentration with this plant community on peat and shellrock soils is probably greater than 10 ppb.

- Periphyton colonization was evident in all experimental mesocosms except the control cells with Aquashade dye treatments. Diel dissolved oxygen and pH patterns were evident in response to algal growth. Net 24-hour primary productivity estimates were relatively low in all treatments (quarterly averages from 1 to 1.8 g $O_2/m^2/d$).

- Macrophytes preferentially colonized and grew in peat-based mesocosms. The peat-based PSTA test cell became dominated by *Typha* and *Hydrilla* while the peat-based Porta-PSTAs became covered with the planted macrophyte spikerush (*Eleocharis cellulosa*). These observations indicate that periphyton cannot be maintained as the dominant plant community on organic soils without significant management activities such as herbicide applications and water level fluctuations.

Relevant data on periphyton-dominated raceways growing on limerock were collected as part of the DBEL SAV/LR project described above (references 7 to 9, 14). Key results for the shallow low-flow and shallow high-flow raceways that were periphyton dominated include:

- At the post-STA research site, shallow, low-velocity periphyton dominated raceways consistently outperformed SAV mesocosms. Average inflow and outflow TP concentrations for these periphyton raceways were 18 and 10 ppb over an 18-month operational period at a HLR of about 11 cm/d.

- Short-term dry-down and subsequent re-wetting had little effect on the periphyton mesocosm performance. Operational performance was back to normal within about 24 hours after re-wetting.

- An average TP settling rate of about 24 m/yr was measured in these systems; however, mass balance information reported after the first 7 months of operation indicated that this TP removal could be completely explained by development of live periphyton biomass with no documented net accretion of sediments.

- A shallow, high-velocity periphyton raceway was able to reduce TP from 17 to 14 ppb at a hydraulic loading rate of about 220 cm/d. This mass removal was also completely accounted for in periphyton biomass accretion and periodic harvesting, and not in accreted sediments.

Some of the key remaining research issues, summarized at the May 17, 2000, Advanced Treatment Technologies workshop (reference 23), are to be addressed during the CH2M HILL Phase 2 research program. Those most related to potential use of PSTA for treatment of post STA surface waters include:

- What are the long-term sustainable TP settling rates and the mechanisms responsible for TP removal?
- What are the effects of full-scale velocities on TP retention in PSTAs?
- What are the effects of dry down on PSTA ecology and on TP retention?
- What are the costs and construction considerations of either placing limerock over organic soils or scraping organic soils down to caprock?
- Can a functional PSTA be created on organic soils using a soil amendment such as lime?
- What is the residuals accretion rate in a PSTA and how and at what cost can these residuals be harvested and disposed of?

The District is currently considering evaluation of water quality changes in naturally-occurring periphyton dominated ecosystems in south Florida for development of a better understanding of long-term PSTA performance. This analysis should be conducted during Phase 2 to document the sustainability of the performance and processes in a PSTA system. The key information needed to support development of PSTA design criteria will be generated by the ongoing mesocosm studies, the field-scale research, review from naturally-occurring systems, and forecast modeling efforts.

12.3 CONSIDERATIONS FOR INCORPORATION OF ADVANCED TREATMENT TECHNOLOGIES IN STA-3/4 DESIGN

As described in the preceding sections, substantive research programs regarding the key candidate ATT are underway by the District and other Everglades restoration stakeholders. Given adequate time for research execution and synthesis, these programs would generate the technical basis for careful and deliberate incorporation of appropriate technologies into the overall STA system to achieve compliance with the final TP standard as cost effectively as possible.

On the basis of the information summarized in this chapter it appears that insufficient information exists at this time to define with confidence the optimal combination of treatment technologies for STA-3/4. Even the technologies that have the best track record under large-scale applications (i.e., CTSS and use of SAV) have considerable cost uncertainties or limited/incomplete operational monitoring records with TP mass balance closure.

In concept, some form of CTSS could be applied in combination with the macrophyte-based design concepts for STA-3/4; however, the required chemical doses are likely to be prohibitively expensive and the possible downstream effects of discharge of the treatment system "effluent" remain unknown. The potential for environmental impacts resulting from residuals management for a facility of this scale also have not been addressed to the extent that warrant full-scale integration with STA-3/4 or any of the other existing STAs at the present time.

Similarly, there currently are insufficient data and design information to incorporate either LICD or MWTS systems into the STA-3/4 designs with any predictable level of confidence. In fact, LICD performance to date indicates that the original concept of low-level chemical applications will not be effective at achieving TP levels that are low enough to address compliance with the anticipated ultimate standard. While additional research is anticipated, the prospects for integration of this ATT with other technology applications are not very positive. Basic research and pilot-scale demonstrations of

MWTS are now underway and completion of these tests is needed prior to consideration of how to integrate it with STA-3/4.

Despite the relative lack of definitive information supporting this position, substantial interest currently exists in exploring the possible integration of the "greener" ATT with STA-3/4 designs. In response to the above-referenced pressures to accelerate the program, SAV seeding of Cell 5 of STA-1W, Cell 3 of STA-2, and Cell 1B of STA-5 has already occurred. There is a prototype for this conversion in that ENR Cell 4 is structurally similar to an SAV-dominated STA. However, concerns remain since:

- There is no validation data set (monitoring data from an independent large-scale SAV dominated wetland) that confirms the magnitude or sustainability of TP removal rates observed in that cell.
- Cell 4 has not been operated in STA mode; hydraulically, flows have been relatively even rather than pulsed as anticipated for STA system operations.
- The effects of dry out on SAV ecology and phosphorus treatment performance have been found to be very detrimental in terms of re-starting after a natural drought event. This low tolerance of the SAV technology for drydown could potentially have important impacts on STA-3/4 performance and operational life.

Similar potential exists for integrating PSTA units into the STA-3/4 design. Such units would clearly only function in a post-STA polishing role, and considerable uncertainty remains regarding how such systems will respond functionally as well as structurally with substantive pulsed flows. It is presently anticipated that PSTA technology will require lower depths in the treatment cells dedicated to PSTA than is presently intended in the design. At all but minor rates of discharge, insufficient hydraulic gradients would remain to permit direction of discharge to pumping stations S-7 and S-8 as is presently intended in the design. The incorporation of PSTA into the downstream elements of STA-3/4 is expected to require the construction of an additional outflow pumping station.

That outflow pumping station would most logically be situated in the vicinity of the existing rock pits near the southwest corner of Cell 2B. The presence of such an outflow pumping station, coupled with other revisions to the L-5 system, would also permit the development of elevated stages in the L-5 Borrow Canal necessary to establish direct discharge to WCA-3A south of STA-3/4 and the Holey Land Wildlife Management Area. Those other revisions would in all probability include:

- Construction of a gated control structure in the L-5 Borrow Canal near S-8.
- Construction of a gated control structure in the L-5 Borrow Canal just west of its confluence with the Discharge Canal along the south lines of Cells 1B and 2B.
- Construction of new control structures in South Levee L-5, together with construction of a spreader canal along the south toe of South Levee L-5, to permit the direct discharges to WCA-3A.
- Removal of the earthen fill across the L-5 Borrow Canal immediately east of its confluence with the discharge canal exiting the rock pits.

It should be noted that the outflow pumping station and other modifications noted above may be needed to establish a sheet flow approximation of discharges to WCA-3A irrespective of whether or not PSTA is eventually incorporated into the design of STA-3/4.

One concept that received attention during the summer of 1999 consisted of a combined system of cattail marshes releasing partially treated waters to SAV cells which in turn discharge to PSTA cells prior to final polished water release south to Water Conservation Area 3A. This concept has gained some additional credibility following the completion of Phase 1 of the SAV and PSTA research projects. SAV appears to work better at higher TP concentrations while PSTA may be the only green technology that can survive at low TP and with periodic drydowns. Given the current (legislatively mandated) completion schedule for STA-3/4, any design of such an integrated system will need to be based on the collective best professional judgement (BPJ) of the design team rather than research-based performance data.

Until more information becomes available for proposing design criteria, an additional, alternative and interim approach could be to design features into STA-3/4 that will facilitate incorporation of one or more ATT in the future. Any design feature that provides flexibility in water routing and depth control would be consistent with this interim approach. Specific suggestions for these types of features were proposed during the Alternatives Analysis stage of STA-3/4 design; these included the following:

- Use of multiple cells separated by embankments (or alternative conveyance constraints) and with independent inlet and outlet water control. This option calls for inclusion of embankments that may not be necessary for emergent wetland cell optimization but that later could be retrofitted for promoting other ecological plant communities.
- Use of variable control slide gates at principal wetland cell outlets over a range of water depths from zero to four4 feet. These gates can be combined with passive secondary water control structures (e.g. weirs, siphons, orifices, and similar structures) or with motorized remote controls that promote capture of storm events with bleed-down periods and allow passage of the largest storm events with minimal detention. Embankment elevations would need to be increased to accommodate the potential for high water stages in all cells. Having a broad range of water depth options in at least some cells will allow future flexibility for establishing specific plant community types.
- Grading cell bottoms to within a tolerance of 0.1 foot to allow sheet flow and depth control. Flat cells allow water depth control at very shallow depths and facilitate water movement throughout the entire cell footprint.
- Incorporation of transverse deep zones for enhanced water distribution at regular intervals along the flow path. These deep zones could also serve as SAV systems embedded within emergent marsh areas. Any longitudinal ditches that might promote short-circuiting should be filled and graded level with the cell bottoms.

Review of the current design concepts documents that many of these recommendations have been incorporated into the design in whole or part. The incorporation of these features has been implemented in the interest of maximizing the treatment performance of STA-3/4 in achieving the Phase 1 goals of the Everglades Forever Act. However, certain of those design features included to date will also contribute to facilitating flexibility in the future final design of this system, and to optimizing performance of the initially constructed STA. Those features include:

- Optimization of inflow and outflow structure placement to encourage achievement of uniform flow distribution across the anticipated STA cells.
- Inclusion of a manageable water control structure (G-383) in the inflow distribution canal to allow blending of Miami River and North New River Canal water inflows, if needed or desired.
- Filling of longitudinal canals and farm ditches to reduce the risk of hydraulic short circuiting. Construction of interior Levees 1 and 4 will be accomplished with materials obtained through degrading of existing internal roads and canal berms rather than through excavation of longitudinal borrow areas to further avoid longitudinal short circuiting.
- Preservation of some of the larger, transverse canals to aid in hydraulic redistribution of flows across the STA cells; strategic insertion of earthen plugs in some of these to inhibit excessive west to east flows.
- Inclusion of additional water control structures to make inter-cell transfers (east to west) possible should such be needed for STA-3/4 performance optimization and/or to allow future construction activities following STA start up.
- Exclusion of the Griffin Property from the footprint of STA-3/4 system leaving the associated borrow pits and adjacent lands available for potential conversion into some form of MWTS-based ATT unit should this be ultimately shown to be a feasible post-STA treatment technology for final TP polishing.
- Segregation of original Cells 1 and 2 into Cells 1A and 1B, and 2A and 2B, by installation of interior Levee 2 and interior Levee 3, with a separate set of internal water control structures (G-375 A-F, and G-378 A-E) for management of flows from north to south and, potentially, to allow differential flow management across the head ends of Cells 1B and 2B. The resultant cells-in-series configuration will provide

significant flexibility should ATT systems need to be integrated within the STA-3/4 footprint. The internal levees and water control structures provide the opportunity to take specific cells offline while potential internal modifications are installed, and multiple options for water shunting exist with the current system of levees and water control structures.

- All water control structures are designed with operable slide gates to permit maximum flexibility in establishment of independent water level control in the various cells, and to facilitate operational changes in the overall distribution of flow in the treatment area interior. Those gates are to be furnished with electric motor operators, and will be equipped to permit full remote monitoring and control via the District's telemetry system.

- Two-dimensional hydrodynamic models of the various treatment cells (see Section 6 of this Plan Formulation document) have been prepared to a greater level of detail than has generally been the case in previous designs for other stormwater treatment areas. In addition, ground surface topography reflected in those models was obtained employing denser field survey data points than was generally the case for previous STA designs. The models are to be furnished to the District's Water Resource Operations group, who will be responsible for day-to-day operations of the treatment area. The models as developed reflect the assumption of a fully developed dense emergent macrophyte vegetative community. It is the District's intent to, during the startup and stabilization period, obtain regular aerial photographic surveys of the treatment area, and to update the models to reflect vegetation type and varying hydraulic resistance as they develop. That information, coupled with data on structure operations and flows, will allow the District to maintain current assessments of the actual hydraulic performance of the treatment area, and to project the potential impact of varying operational strategies on the promotion of improved treatment performance.

Lastly, it is noted that the degrading of internal roads and canal berms, coupled with required excavations for primary project canals, is currently expected to generate a surplus of fill material. This surplus material will be strategically placed along certain of the project levees in anticipation of potential use if additional internal berms become necessary in support of ATT integration.

In summary, it is clear that the current STA-3/4 design incorporates a number of key features that provide flexibility for system operations and performance optimization whether or not ATT units are ultimately identified for inclusion within the existing STA footprint. Should this be determined to be necessary, the internal levees and water control structures can be used to shunt water flows to cells remaining on line while the others are modified however necessary to allow hydraulic and phosphorus treatment upgrade implementation. As is the case for most of the District's Everglades Restoration efforts, adaptive management will continue to be needed to ensure that STA design and construction efforts remain nimble enough to respond as new and better information becomes available regarding the technical, economic, and environmental feasibility of the various ATT options.

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List of Acronyms

BMPs	best management practices
BPJ	best professional judgement
cm/d	centimeters per day
CTSS	chemical treatment/solids separation
EAA	Everglades Agricultural Area
EFA	Everglades Forever Act
ENR	Everglades Nutrient Removal
EPA	Everglades Protection Area
DBEL	DB Environmental Laboratories
FDEP	Florida Department of Environmental Protection
LICD	low intensity chemical dosing
mg/L	milligrams per liter
m/yr	meters per year
MWTS	managed wetland treatment system
ppb	parts per billion
PSTA	periphyton-based stormwater treatment areas
SAV	Submerged Aquatic Vegetation
SAV/LR	Submerged Aquatic Vegetation/Limerock
STA	Stormwater Treatment Area